

Fourth Annual Conference on Carbon Capture & Sequestration



*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

Regulatory Analysis

Review of Existing Injection Well Permit Regulations and Expectations of Future Geologic Sequestration CO₂ Regulations with Monitoring Conditions

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Overview

- Review of Class I, II, V well classes, Permits
- Frio Brine CO₂ Pilot – (Hybrid) Permit Process
- Future (Geologic Sequestration) Permit and Regulatory Challenges, Precedents – an Injection Well Consultant's viewpoint
- Implementing the Technology – potential areas for Amendment to Injection Well regulations, additional Monitoring

Injection Well Usage for Disposal/Storage

Wastes

- Chemical Manufacturing
- Municipal (sewage)
- Petroleum Refining
- Mineral Processing
- Superfund wastes
- Petroleum Production saltwater
- Food Processing
- Air Scrubber wastes
- Acid gas processing plant wastes
- Solids, Fracture slurry
- Norm wastes
- Bio-solids (sewage)
- Nuclear Waste Disposal (Russia)

Products

- Aquifer Storage
- Underground Natural Gas Storage
- LNG & Cavern Storage
- Underground & Cavern Petroleum Product Storage
- Geothermal Power

Future Waste or Product??

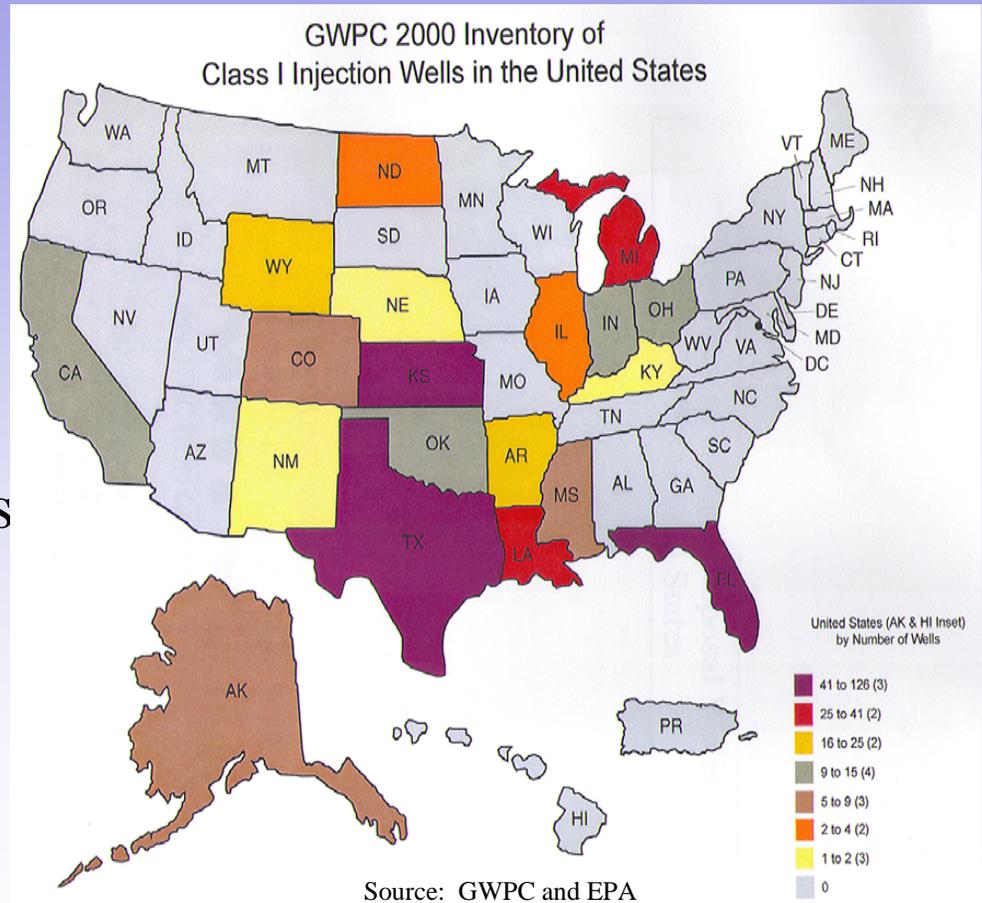
- CO₂ Sequestration/Storage/Disposal
- Stack Gases: NO_x, H₂S, SO₂

General Review Injection Well Classes

- Class I --Hazardous & Non-Hazardous Process wastes ~ 455 – 500 (USA) wells
 - EPA & State Environmental Agencies
- Class II – Petroleum produced waste fluids ~ 150,000 wells
 - State Oil & Gas, Environmental Agencies
- Class V --Non-Hazardous liquids ~ 500,000 - 685,000 wells
 - EPA and State Environmental Agencies
 - Sources: EPA and GWPC

Class I Injection Well Population

- ~ 486 Wells
- Most Stringent Class
- TX Largest Industrial
 - Large CO₂ emissions
- Regulatory Base established
- Historical Safe operations
- Community acceptance
 - Non-Haz = 251 wells
 - Haz = 122 wells
 - Muni = 111 wells

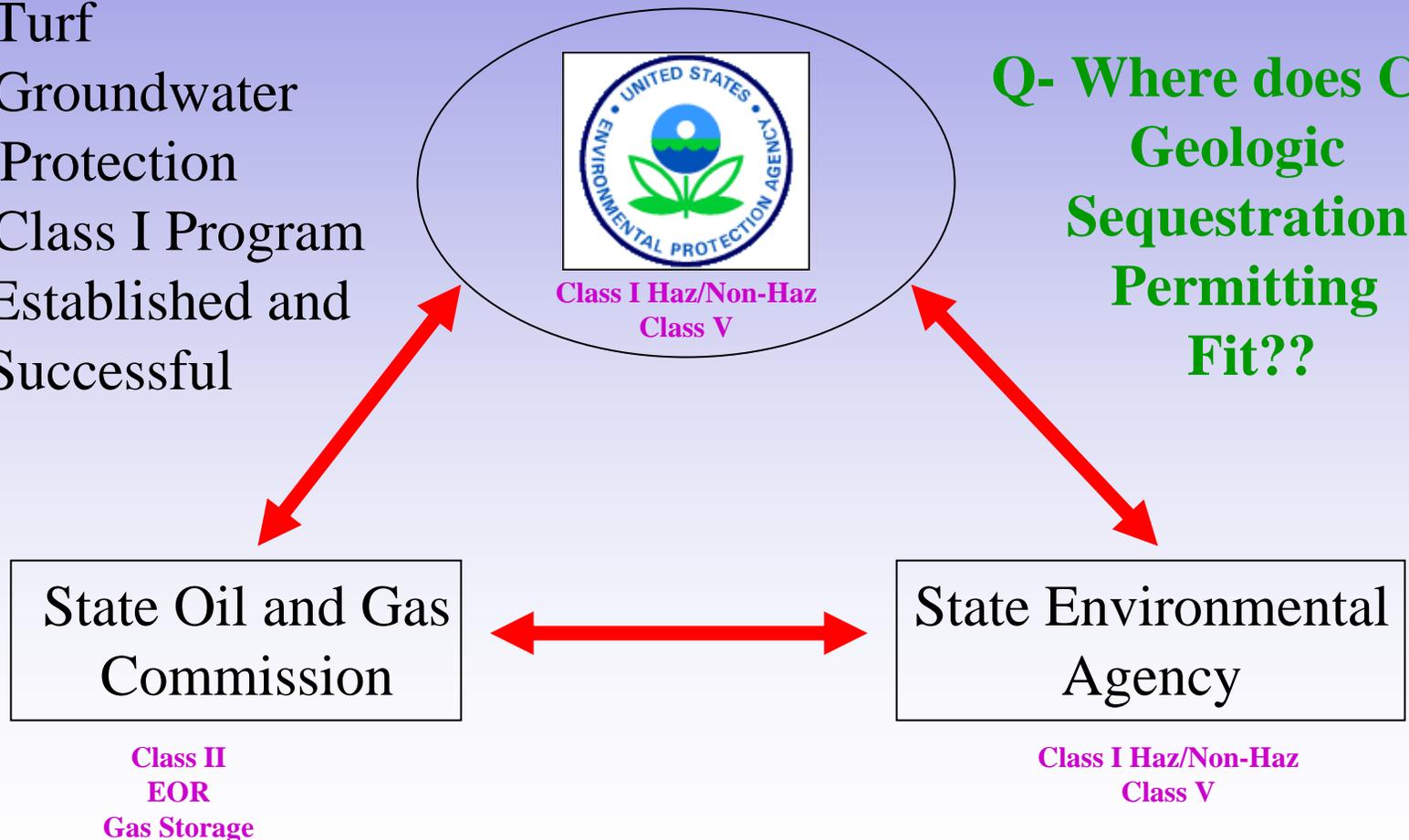


Regulatory Jurisdiction 'Bermuda' Triangle

- Regulations overlap
- Turf
- Groundwater Protection
- Class I Program Established and Successful

Challenge:

Q- Where does CO₂ Geologic Sequestration Permitting Fit??



Frio Brine Pilot – A Hybrid Permit



TCEQ & RRC Permit Comparison

Class I Well

- Technical Demonstration and Report for Haz (EPA-Petition) /Non-Haz wastes
- Geology, Modeling evaluation
- Minimum 2.5-mile Area of Review (AOR)
 - Identify all wells, cement plugs, etc
- Stringent Well Construction & tubular Standards
 - Surface casing depths, protect USDW
 - Continuous cement, isolation
 - Corrosion, acid resistance materials
- Injectate/Waste Compatibility
- Notify Adjacent land/mineral owners
- Surface Facilities description, P.E. certified
- Up to 360 days for Permit review

Permit Conditions

- 10-Year term
- Continuous Monitoring, MIT, annulus
- Volume, Rate, MASIP limitations
- Public notice, comment

Class V Well (other, experimental, pilot)

- Application form, Non-Haz wastes
- Geology, Basic Modeling evaluation
- Fixed 0.25-mile Area of Review (AOR)
 - Identify all wells, cement plugs, etc.
- Less stringent Well Construction
 - Protect USDW
- Injectate description, facilities certification
- Notify Adjacent and underlying land/mineral ownership
- Permit Review expedited ~60 days

Permit Conditions

- Continuous Monitoring, MIT, annulus
- Volume & Rate Limitation
- MASIP (Fracture) Pressure Limitation

Class II Well (SWD, E&P produced fluid)

- Application form, 30-60 days (RRC)
- Fixed 0.25 mile Area of Review
- Notify landowner, leaseowner
- No term, open-ended, 1-2 yrs inactivity

Hybrid Permit for Frio Brine Pilot -- Dayton, Texas

- Challenged TCEQ, with precedent setting areas, out-of-box thinking solutions
- Adapted Class V (experimental/other) Well Rules
- Under TCEQ rules (and EPA Guidance) a combined Hybrid Class V and Class I Permit was authorized (10-month term, re-authorized for additional follow-up testing)
- More stringent Class I Rules & Conditions Included:
 - Geologic, Reservoir investigations, 3-D Seismic viewing, Modeling evaluation
 - Salt Dome area, complex faulting, abandoned wells identification
 - Area of Review, 0.25-mile fixed radius from injection well
 - Drilling new Well, included Formation Cores, confining and injection intervals.
- Included Class I Well Construction Standards (stringent) Add-ons
 - Well construction, continuous cement & isolation
 - Surface Casing depth
 - USDW Protection of usable water (<3000 mg/l)
- Surface/Mineral Ownership Identification/notification
- Public Notice not held, Community Well Information Meetings, Press held.

Hybrid Permit for Frio Brine Pilot

- New Injection Well permitted, drilled and configured for CO₂ Pilot, with USDW Protection— Surface Casing, Cement sheath, circulate cement up around Protection Casing
- Well Completion System, Packer, Tubing, Annulus
- Mechanical Integrity Testing (MIT)
- Pilot Test, Injection Operation Conditions--
 - Monitoring program—continuous during injection period
 - Limitation of Max. Allowable Surface Injection Pressure (MASIP)
 - MASIP well below fracture gradient of Frio Sand
 - Limitation of CO₂ injected volume
 - Limitation of injection term (short-term duration due to corrosion)
- Cement Evaluation of Observation Well (50-yr old oil well) 100 feet away, squeeze cemented for interval isolation, testing, and USDW protection
- TCEQ Personnel observed and commented on all remedial well work and operations during the pilot test phases

Summary of Permit Results for Frio Brine Pilot

- Expedited Permit Review time from TCEQ staff
- Notification, Consultation, Interaction with EPA Region 6 staff
- No public notice, in lieu of local community meetings
- Well Construction design upgraded, Cement Bond/Isolation evaluation, Surface Facilities included, certified by a Texas P.E.
- TCEQ witnessed key areas in new Well Drilling, Surface Casing, Cementing, Logging, Setting Protection Casing

Frio Brine Pilot -- Regulatory 'a la Carte, Cafeteria' Permit



Future Permit & Regulatory Challenges Geologic Sequestration

A Consultant's View

Protection of USDWs

- Adopt, adapt EPA Non-Endangerment, No-Migration Demonstration Standards from Class I well rules
 - Add separate category for GEOSEQ wells, e.g. Class I-S
- Add to existing set of in-place regulations, critical monitoring and key ownership items (where needed)
 - Executive Director currently has ability and authority to process applications make decisions on a site-by-site basis
 - Siting Criteria should deny Permit to unsuitable sites
 - Rulings on CO₂ ownership, recovery, mineral claims, etc.

– Protect USDWs

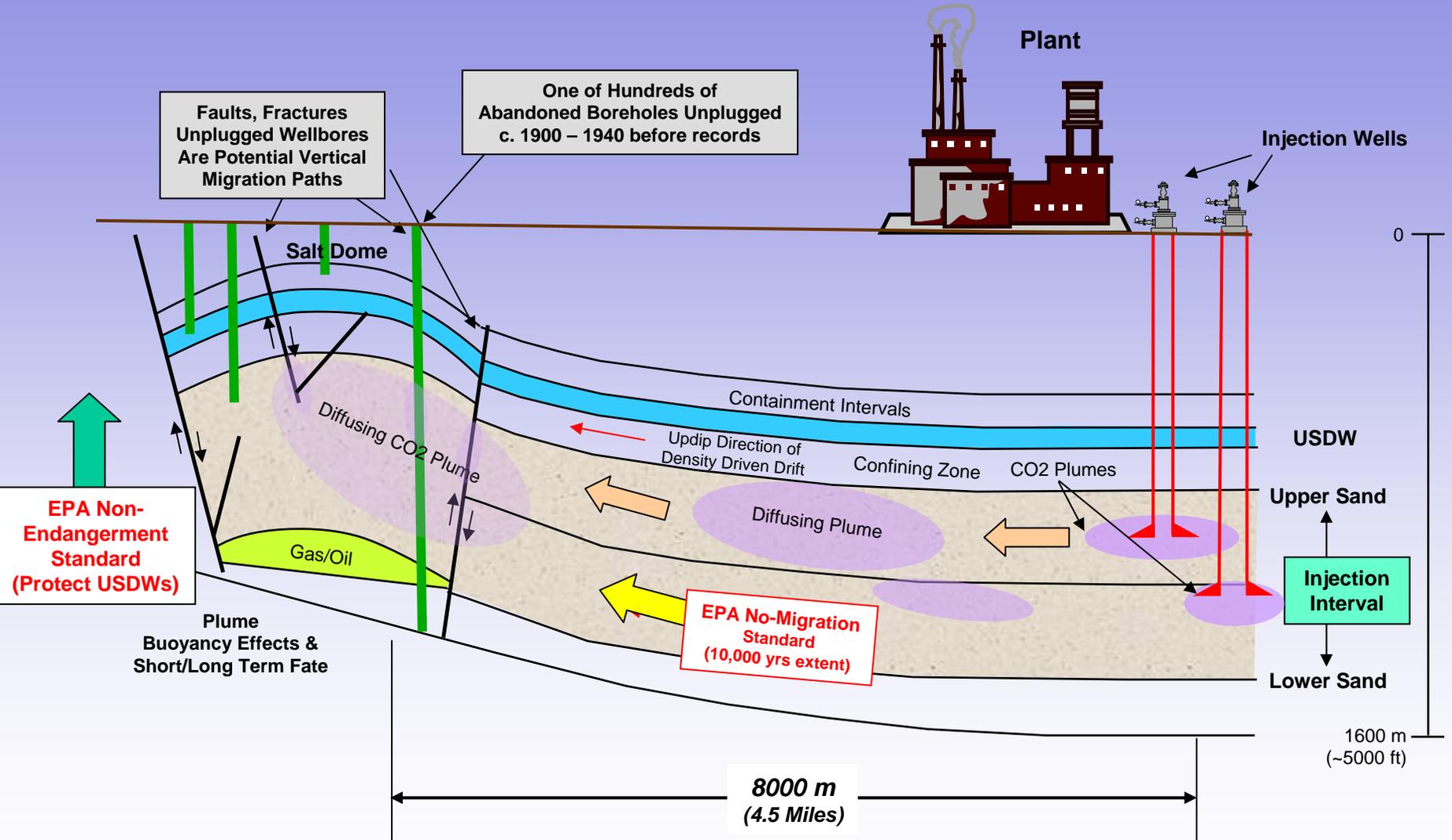


Goal is no Perrier groundwater!!

Regulatory Issues and ‘Hot Buttons’

- Human Safety, Health and the Environment concerns
- Uncertainties – Regulators, and the Public dislike gray areas
- Plume Migration Modeling (buoyancy, extent, confidence)
 - Class I Haz wells utilize ‘worst-case’ modeling, bounding the problem
- Geologic Parameters (conservative injection/confinement)
- Accepted Reservoir and Transport Models
 - Use 100, 1,000, or 10,000 Year Time Frame?
- Area of Review – off-site, abandoned borehole assessment0
 - Cement plugs; potential CO₂ corrosion on casing, plume buoyancy effects
- Inject above or below Frac Pressure
 - Class I < frac pressure; except during initial well development phase
 - Petroleum production wells frac formations, enhance rates
- Well Construction Standards, corrosion resistance, waste fluid-materials compatibility
- Monitoring, Annual Plume Tracking, Volume, etc.

Plume Buoyancy Effects on Abandoned Boreholes



A Challenge to Model, to Monitor, and make a Technical Permit Demonstration



Implementing the Technology

**Potential Areas for Amendment to
Injection Well Regulations,
Additional Monitoring, etc.**

Consultant's Viewpoint

- CO₂ injection technology remains a better fit under Class I vs., Class II or V well programs, or State Oil and Gas Commissions.
 - Due to existing regulations, UIC Program, widespread knowledge base of injection well operators, many similarities are present with Class I wells.
- Injection Wells are a viable and proven Technology from the Petroleum Industry and Class I programs to eliminate wastes from the Biosphere.
 - Risk assessment studies have shown high confidence and low risk to using this technology for disposal and storage
- Minor Amendments to existing Injection Well regulations could implement CO₂ disposal/storage technology.
 - CO₂ ownership, mineral rulings, more stringent techno-based Monitoring likely required

Suggested Amended Regulations/Conditions

Additional Permit Conditions May be Required

Items Addressed under Existing Class I program:

- Consider more detailed geology evaluation to assess fault sealing capability, geologic structures, and potential for migration
- Perform more Modeling scenarios to address physical geologic system and injectate variability driving mechanisms
- Use more stringent well construction standards for injection well(s), and review any potential remediation of substandard abandoned wells
- Inject below fracture pressure, unless added monitoring can demonstrate no vertical migration of CO₂ or GHG emissions
- More over-lying buffer intervals, deeper injection horizons to mitigate potential vertical migration

Suggested add-ons in the form of Permit Conditions:

- Consider Periodic Monitoring Techniques using surface seismic, cross-well imaging, reservoir pressure testing and borehole logging tools (RST) to determine the leading edge of plume transport and injection interval
- Consider Monitor Wells up-dip of buoyant plume (site specific)
- Resolution of Mineral ownership, eminent domain, capture/recovery of CO₂ must be determined to avoid legal challenges or future claims on CO₂

Discussion Items

- Consider separate sub-category for CO₂ injection wells under Class I jurisdiction
- Define Storage? Disposal? Temporary vs. Permanent
- Define CO₂, or other stack gases, NO_x, H₂S, SO₂
- Consider Monitor Wells where appropriate/useful
- More detailed geology, reservoir, faulting, assessment
- Consider supplemental Seismic monitoring every 5 years to track plume extent
- Consider additional CO₂ detection logging techniques for monitoring, plume detection, CO₂ saturation

Out-of-the-Box Observations

- Geologic Siting criteria should be more stringent, some sites may not be favorable for injection
- An Integration of Pressure Monitoring, Fluid and injectate data, assessing abandoned borehole data must be performed
- Determine actual formation fracture gradient from geomechanics evaluation, set safety factor for injection rate
- Capture, Storage, Disposal?? A Waste or a Commodity??
CO₂, H₂S, NO_x, SO₂
- Plant Operators have no incentive to segregate pure CO₂, unless commodity market is there, more incentive exists for disposal as a waste (parallels with Class I industrial wastes)
- Use of CO₂ for EOR in mature U.S. oilfields is labor intensive, oil and gas companies not staffed for it, requires more tax incentives, credits to assist in market creation.
- Higher Oil Commodity Prices \$ 50/bbl provide >\$ 30/ton CO₂ implied commodity value (price depends on purity/grade)

Implementing the Technology

- Class I Well Operators/Consultants believe this technology is very viable for GHG emissions
- Offers most ‘bang-for-the buck’ for near-term emissions reduction
- Requires minimal regulatory add-on, more evaluation, monitoring suggested
- Can be coupled to the successful UIC Program
- Requires key definitions – disposal (Class I rules) or storage (new rules)

Greenhouse gas goes underground

